establish communications and in a seamless transition, the far field link continues to communicate with the device after removal of the wand from the vicinity of the implantable medical device. For example, in one embodiment, a wand having an inductive coil is temporarily brought near the chest wall of the patient in a clinical setting, and upon removal of the wand from near the patient, communications continue using a far field link. At the conclusion of the session, marked by receipt of a signal received via the far field link, or upon a signal transmitted from the near field wand, the far field link is disabled. In one embodiment, the far field link is used to transmit new parameters or instruction code to the implantable medical device and the new parameters or code are triggered for implementation upon receipt of a command transmitted via the inductive coil or far field link.

Alternate Embodiments

In various embodiments, all telemetry with the implanted medical device is communicated using a far field transmitter, far field receiver, or a far field transceiver. Fig. 9 illustrates an embodiment of an implanted medical device having medical module 240 coupled to a far field transceiver 230D via telemetry data bus 215. The telemetry system, including far field transceiver 230D, of the implanted medical device is operated according to a duty cycle and the duty cycle is compatible with the operation of a suitable programmer. For example, the programmer may also be operated according to a complementary duty cycle or operated continuously.

In one embodiment, the medical device and the programmer communicate on a peer-to-peer basis and not on the basis of a master-slave relationship. For example, in one embodiment, the medical device and the programmer are cycled in phase according to a predetermined schedule. In this embodiment, the medical device and the programmer operate without establishing a master-slave relationship wherein one unit is superior to the other unit. By way of an example, in a system with a field communication link, the implanted medical device may attempt to receive data, or transmit data, without having first received an acknowledgment or ready signal from the programmer.

In one embodiment, the implantable medical device and the programmer engage in a handshaking routine wherein each device has substantially equal autonomy.

The duty cycle of the implantable medical device may correspond to that of the programmer. For example, a 10% duty cycle of a medical device based on a 10 second period (that is, the device may transmit, or receive, a wireless signal for one second followed by nine seconds of dormancy) would be able to communicate with a programmer operated on a 10% duty cycle based on a 5 second period (that is, the programmer is active for one second followed by four seconds of dormancy). The medical device may also communicate with a programmer that is continuously active. In one embodiment, the communication link of the medical device is operated according to a duty cycle providing one second of activity followed by several seconds of dormancy.

In one embodiment, the duration of the window during which far field communications may be conducted, is dynamically adjustable. For example, after having established a communication link during the active period of a duty cycle, the programmer may instruct the medical device to maintain the far field communication link for a programmable period of time which differs from a duty cycle of the medical device. In this way, for example, the programmer can conduct uninterrupted communications with the medical device. In addition, the programmer may instruct the medical device to terminate the far field communication link at a predetermined time and without regard for the duty cycle.

In one embodiment, a near field link is used to mark the beginning of a session during which the far field communication link is available. The duration of the subsequent far field communication session may be determined by a duty cycle, fixed time period or an instruction or parameter received during the communication session. For example, in one embodiment, the far field communication link is available according to a predetermined duty cycle. Thus, the far field link is terminated upon the expiration of a predetermined window. As another example, the far field communication link may be available during the course of a medical procedure, such as, device implantation. In such an embodiment, the far field link may become available at the start of the procedure

after first having been triggered by a near field communication link. The far field link may remain available for a predetermined duration, typically sufficient to allow completion of a particular medical procedure. In another example, the far field communication link is terminated upon receipt of a predetermined command or instruction received via the far field link or near field link. A terminate command may truncate the duty cycle that otherwise would determine the window duration.

In some regions of the world, or in certain locations, regulations may preclude the use of far field radio frequency transmissions. For example, in Japan, certain frequencies that are readily available in the United States of America are not available for far field RF transmissions. As another example, Federal Aviation Regulations enforced by the Federal Aviation Administration (FAA) prohibit the use of certain far field transmissions while airborne.

In such cases, these restrictions or regulations are satisfied by an embodiment of the present system having a configuration that does not transmit a far field RF signal unless it first receives a far field RF signal. In one embodiment, the near field link or far field link first receives a wake up signal before the far field transmitter is operated. In one embodiment, the implantable medical device receives and transmits using the same communication link. For example, if a far field signal is received, then a far field signal is transmitted. The far field signal may include an acknowledgment.

In one embodiment, the programmer is burdened with the task of arbitrating the communication links. The programmer is considered more robust since power may be derived from a metered line service or batteries that can be replaced without surgical procedures. In various embodiments, the external programmer is operated continuously or according to a duty cycle.

For example, the external programmer may be used with many different implantable medical devices, each having a unique identification code. The far field transmitter of the programmer may be operated continuously and the transmitted signal can be tailored to correspond with a particular implantable medical device by proper selection of the identification code. To establish a communication session with a particular implantable medical device, the

programmer may continuously transmit a key and listen for a response. In this manner, the programmer need not know precisely the timing sequence and duty cycle of each individual implantable medical device. After the targeted implantable medical device wakes up and receives the far field transmission, the device transmit a far field acknowledgment signal.

In one embodiment, the duty cycle of the implantable medical device can be dynamically adjusted. For example, a low power consumption duty cycle may be operative during times when the implantable medical device is away from a medical facility, a medium power consumption duty cycle may be operative during times near a medical facility and a high power consumption duty cycle may be operative during a clinician visit at a medical facility. The level of power consumption may be associated with different duty cycles. For example, in one embodiment, the low power consumption duty cycle provides that the far field receiver is operated for one time period in 10,000 time periods whereas the far field receiver is operated continuously in the high power consumption duty cycle. In one embodiment, the particular duty cycle is selected based on receiving an external signal (near field or far field) or by an internal parameter detected by the implantable medical device.

In one embodiment, synchronization includes receiving a magnetic signal. The magnetic signal may be received from a wand coupled to a programmer. The signal may correspond to an edge or transition of a magnetic field strength or magnetic alignment. In one embodiment, the implantable medical device responds to a minimum magnetic field strength.

Conclusion

Other embodiments of the present system are also contemplated. For example, in one embodiment, the implantable medical device, or programmer, has more than two transmitters, transceivers, or receivers. In one embodiment, an implantable medical device is adapted to include a single transceiver having a plurality of operational modes wherein one mode includes transmitting, or receiving, a substantial signal at a near field strength and a second mode includes transmitting, or receiving, a substantial signal at a far field strength.

Although the invention has been described in conjunction with the foregoing specific embodiment, many alternatives, variations, and modifications will be apparent to those of ordinary skill in the art. Such alternatives, variations, and modifications are intended to fall within the scope of the following appended claims.

WHAT IS CLAIMED IS:

1. A system comprising:

an implantable medical device including an electronic circuit;

a near field antenna connected to the electronic circuit for conducting inductively coupled wireless communication with the implantable medical device; and

a far field antenna connected to the electronic circuit for conducting radio frequency (RF) wireless communication with the implantable medical device according to a duty cycle.

2. The system of claim 1, wherein the electronic circuit includes a cardiac rhythm management device.

3. The system of any of claims 1 and 2, wherein the near field antenna includes a coil.

4. The system of any of claims 1, 2 and 3, wherein the far field antenna includes a dipole antenna.

5. The system of any of claims 1, 2 and 3, wherein the far field antenna includes a monopole antenna.

6. The system of any of claims 1, 2 and 3, wherein the far field antenna includes a conductor of a therapy lead.

7. The system of any of claims 1, 2 and 3, wherein the far field antenna includes a circumferential antenna.

8. The system of any of the foregoing claims, wherein the electronic circuit includes a programmable therapy circuit.

9. The system of any of the foregoing claims, wherein the electronic circuit includes a patient monitoring circuit.

10. The system of any of the foregoing claims, wherein the electronic circuit includes a diagnostic circuit.

11. The system of any of the foregoing claims, wherein the electronic circuit includes an RF transmitter, an RF receiver, or an RF transceiver.

12. The system of any of the foregoing claims, further comprising a programmer for wirelessly communicating with the implantable medical device.

13. The system of claim 12, further comprising an external coil connected to the programmer.

14. The system of claim 12, further comprising an RF antenna connected to the programmer.

15. The system of claim 12, further comprising a set of instructions adapted for execution by the programmer for receiving a signal from the implantable medical device.

16. The system of claim 12, further comprising a set of instructions adapted for execution by the programmer for transmitting a signal to the implantable medical device.

17. A system comprising:

an implantable medical device;

a far field communication means coupled to the implantable medical device and adapted to communicate during a portion of a duty cycle;

a near field communication means coupled to the implantable medical device.

18. The system of claim 17 wherein the implantable medical device includes a processor means, wherein the processor means is adapted to control the operation of the far field communication means.

19. The system of any of claims 17 and 18 wherein the far field communication means is adapted to operate based on a signal received using the near field communication means.

20. A method comprising:

coupling a plurality of wireless transmitters of an implantable medical device to a circuit of the device; and

programming the device to select one or more of the plurality of wireless transmitters for transmitting an outbound signal.

21. The method of claim 20 wherein programming the device to select one or more of the plurality of wireless transmitters includes programming the device to select a transmitter having an inductively coupled antenna.

22. The method of any of claims 20 and 21 wherein programming the device to select one or more of the plurality of wireless transmitters includes programming the device to select a transmitter having a far field radiation antenna.

23. The method of any of claims 20, 21 and 22 further comprising providing a receiver adapted to receive the outbound signal at a far field distance from the implantable medical device.

24. The method of any of claims 20, 21, 22 and 23 wherein programming the device to select one or more of the plurality of wireless transmitters for transmitting an outbound signal includes programming the device to deselect a far field radio frequency (RF) transmitter of the plurality of wireless transmitters.

25. The method of any of claims 20, 21, 22, 23 and 24 wherein coupling a plurality of wireless transmitters includes coupling a transmitter adapted for propagating an RF signal.

26. The method of any of claims 20, 21, 22, 23, 24 and 25 further comprising providing circuitry for receiving physiological data at the implantable medical device.

27. The method of any of claims 20, 21, 22, 23, 24, 25 and 26 further comprising providing circuitry for receiving an operational parameter at the implantable medical device.

28. The method of any of claims 20, 21, 22, 23, 24, 25, 26 and 27 further comprising coupling at least one wireless receiver to the circuit.

29. The method of claim 28, further comprising providing programming to decode data received by a wireless receiver selected from the at least one wireless receiver.

30. The method of any of claims 28 and 29, further comprising providing programming to store data in a memory of the implantable medical device based on an inbound signal received by a wireless receiver selected from the at least one wireless receiver.

31. The method of any of claims 28, 29 and 30 further comprising providing programming to operate the implantable medical device based on data encoded in the inbound signal.

32. A method comprising:

receiving an inbound wireless signal at an implantable medical device;

selecting one of a plurality of receivers of the implantable medical device; and

at the output of the selected receiver, decoding data from the inbound wireless signal.

33. The method of claim 32, further comprising storing the decoded data in a memory of the implantable medical device

34. The method of any of claims 32 and 33 further comprising delivering therapy based on the decoded data.

35. The method of any of claims 32, 33 and 34 wherein receiving an inbound wireless signal includes receiving an inbound wireless signal at a far field distance from a transmitter that propagated the inbound wireless signal.

36. The method of any of claims 32, 33, 34 and 35 wherein receiving an inbound wireless signal includes receiving an operational parameter for the implantable medical device.

37. The method of any of claims 32, 33, 34, 35 and 36 further comprising storing data in a memory of the implantable medical device based on the decoded data.

38. The method of any of claims 32, 33, 34, 35, 36 and 37 further comprising operating the implantable medical device based on the decoded data.

39. A method comprising:
receiving a first wireless signal from a near field transmission source;
opening a channel to communicate using a wireless far field link;
receiving data on the channel;
closing the channel after a predetermined period;
storing the data in memory of an implantable medical device; and
operating the implantable medical device based on the memory.

40. The method of claim 39, wherein receiving a first wireless signal includes receiving an inductively coupled signal.

41. The method of any of claims 39 and 40 wherein opening a channel includes powering a radio frequency receiver.

42. The method of any of claims 39, 40 and 41 further comprising receiving an update command before operating the implantable medical device based on the memory.

43. The method of claim 42 wherein receiving an update command includes receiving an update command from the near field transmission source.

44. A method comprising:

powering a near field link of an implantable medical device;

powering a far field receiver of the device according to a duty cycle;

transmitting a near field acknowledge signal using the near field link if a near field signal is received; and

powering a far field transmitter of the device after having received a far field key signal using the far field receiver during a time when the far field receiver is powered.

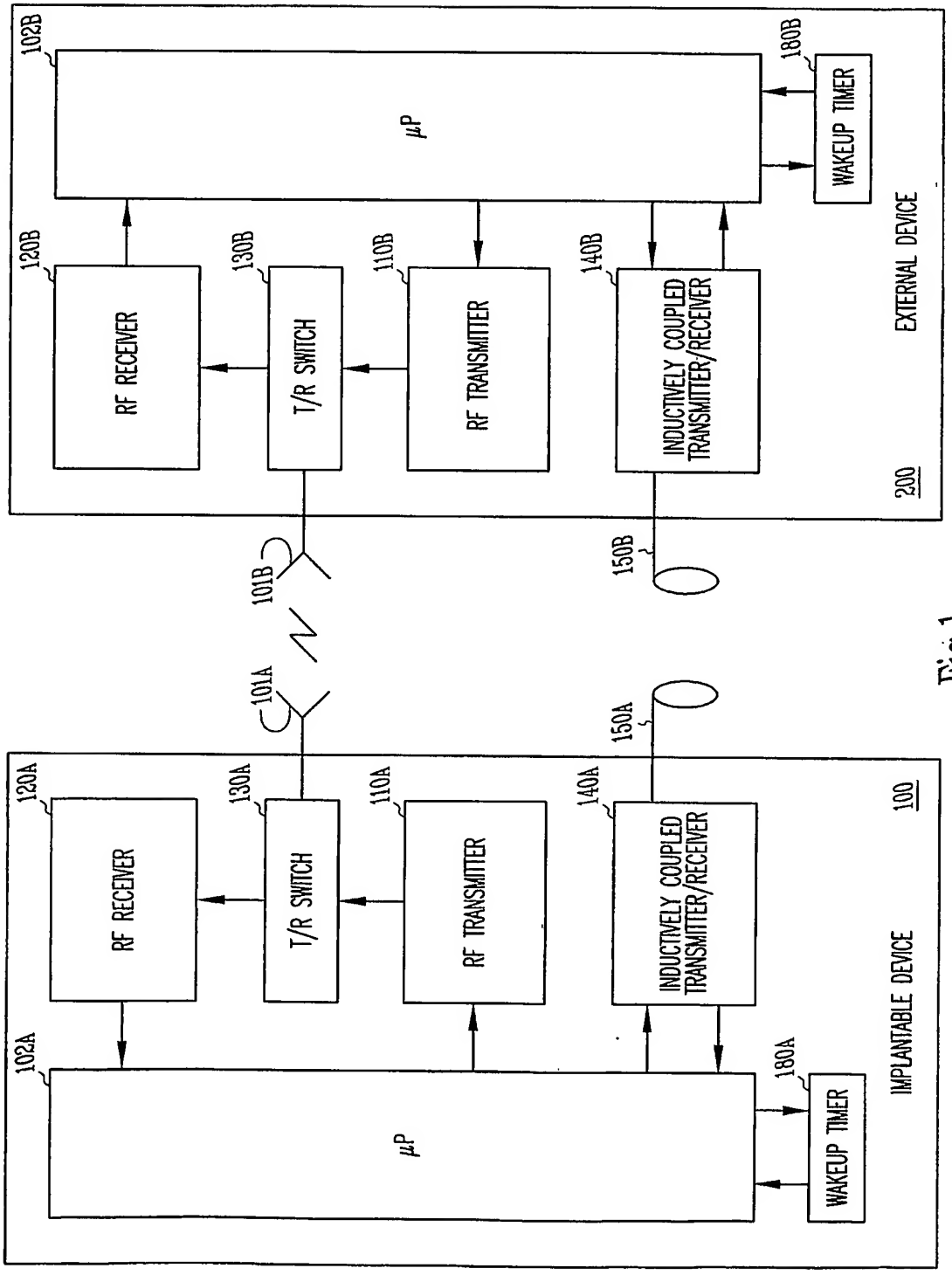
45. The method of claim 44 further comprising transmitting a far field acknowledge signal using the far field transmitter.

46. The method of any of claims 44 and 45 further comprising continuously powering the far field receiver after receiving a suspend duty cycle signal.

47. The method of claim 46 wherein receiving the suspend duty cycle signal includes receiving a near field signal.

48. The method of claim 46 wherein receiving the suspend duty cycle signal includes receiving a far field signal.

49. The method of any of claims 44, 45, 46, 47 and 48 wherein powering the near field link includes continuously powering the near field link.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μP
180B
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120B
RF RECEIVER
130B
T/R SWITCH
110B
RF TRANSMITTER
140B
INDUCTIVELY COUPLED TRANSMITTER/RECEIVER
EXTERNAL DEVICE
200
101B
150B
101A
150A
120A
RF RECEIVER
130A
T/R SWITCH
110A
RF TRANSMITTER
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μP
180A
WAKEUP TIMER
IMPLANTABLE DEVICE
100

Fig.1

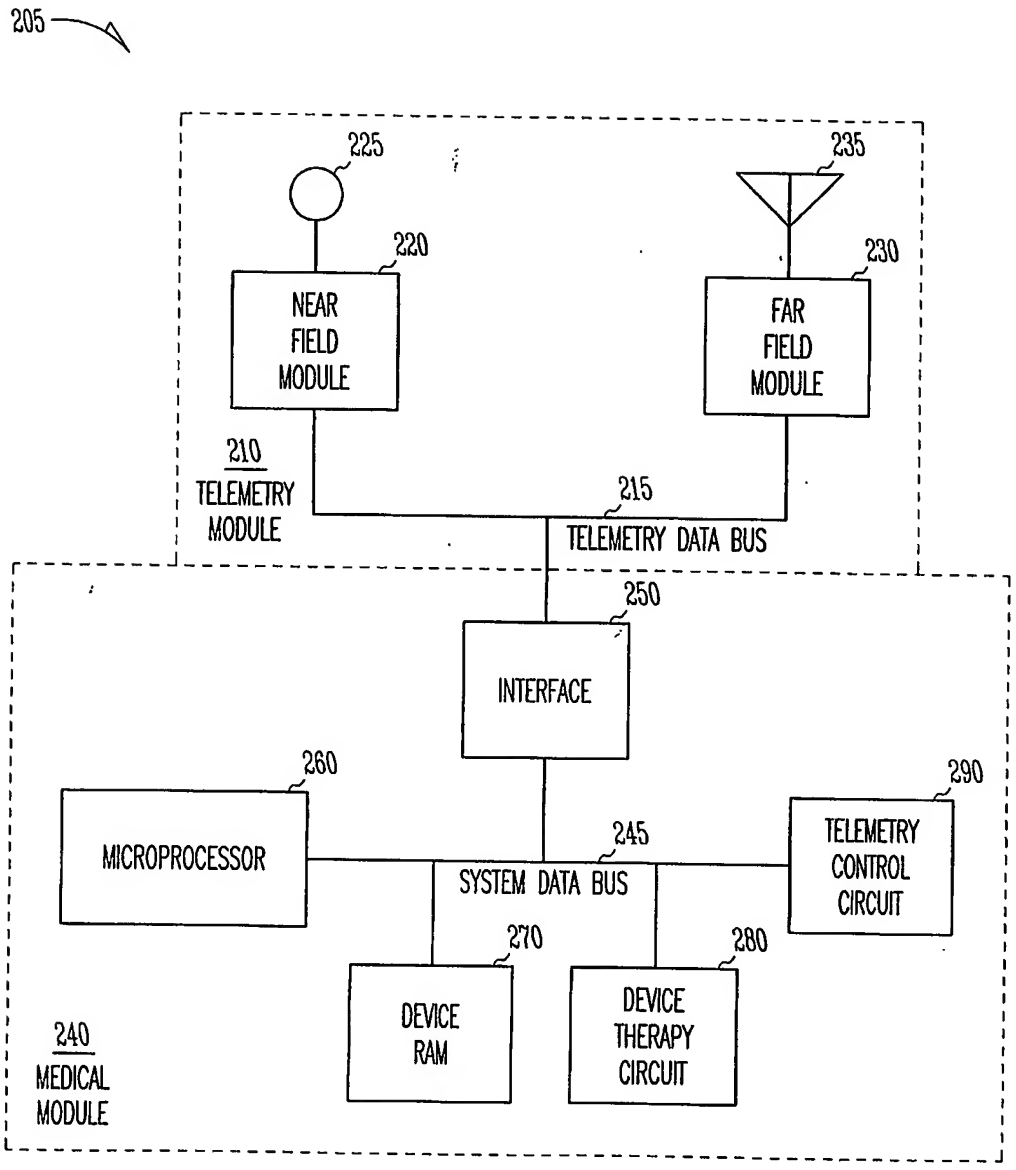
205
225
235
220
230
NEAR FIELD MODULE
FAR FIELD MODULE
210
TELEMETRY MODULE
215
TELEMETRY DATA BUS
250
INTERFACE
260
290
MICROPROCESSOR
245
SYSTEM DATA BUS
TELEMETRY CONTROL CIRCUIT
270
280
DEVICE RAM
DEVICE THERAPY CIRCUIT
240
MEDICAL MODULE

Fig.2

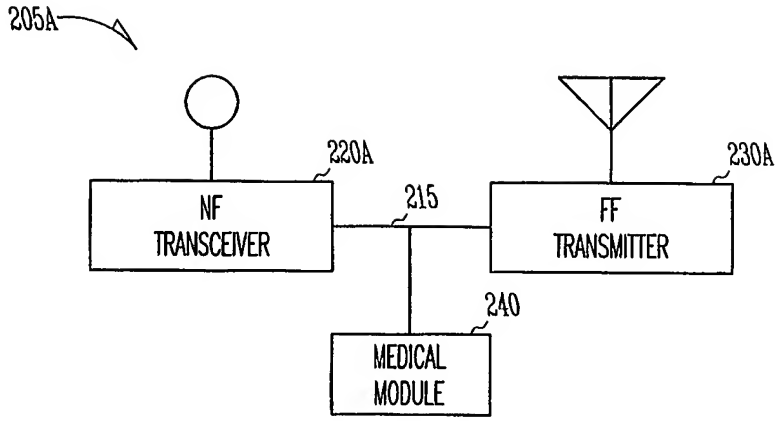

Fig.3

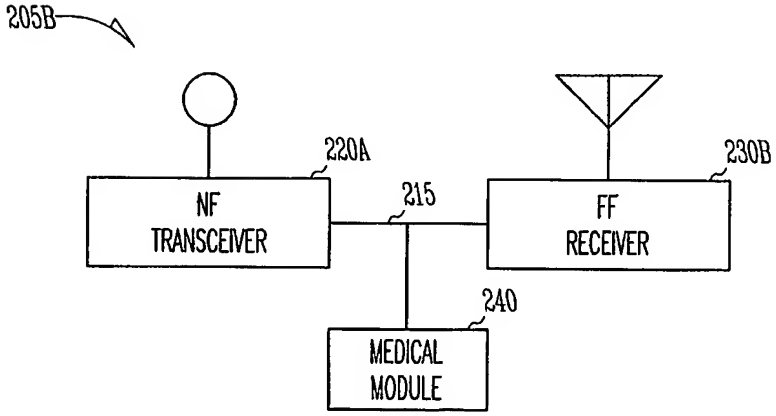

Fig.4

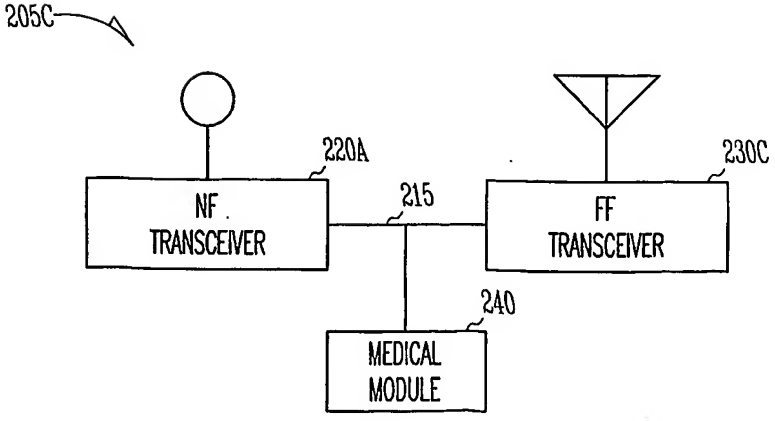

Fig.5

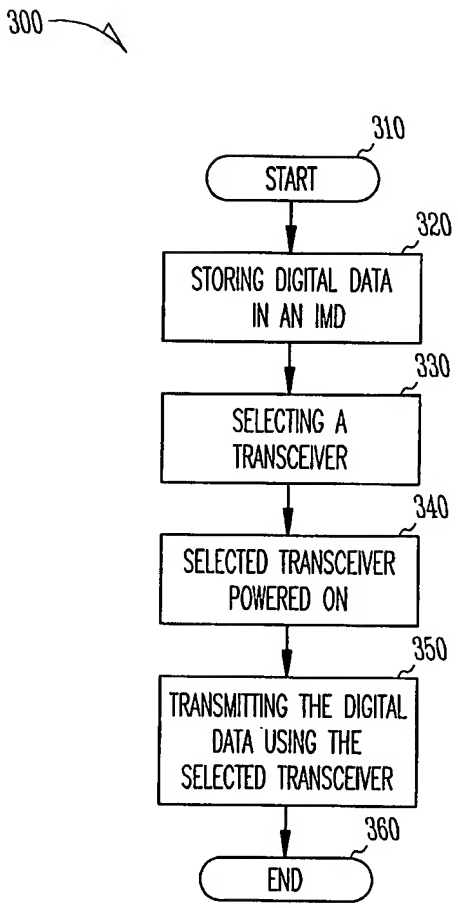
300
310
START
320
STORING DIGITAL DATA IN AN IMD
330
SELECTING A TRANSCEIVER
340
SELECTED TRANSCEIVER POWERED ON
350
TRANSMITTING THE DIGITAL DATA USING THE SELECTED TRANSCEIVER
360
END

Fig.6

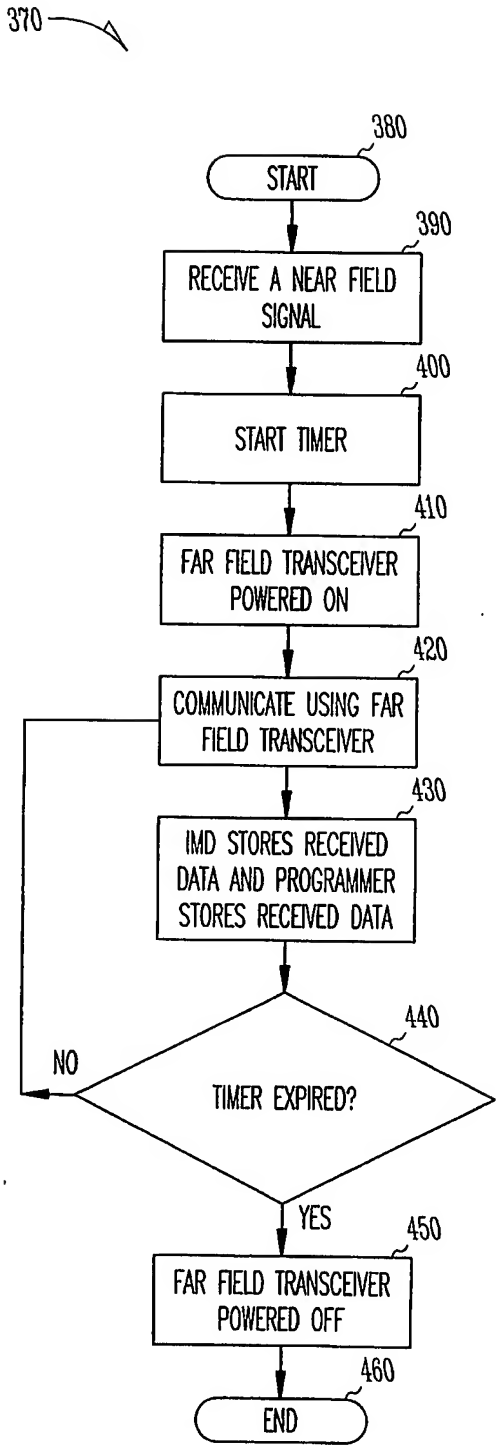
370
380
START
390
RECEIVE A NEAR FIELD SIGNAL
400
START TIMER
410
FAR FIELD TRANSCEIVER POWERED ON
420
COMMUNICATE USING FAR FIELD TRANSCEIVER
430
IMD STORES RECEIVED DATA AND PROGRAMMER STORES RECEIVED DATA
440
TIMER EXPIRED?
NO
YES
450
FAR FIELD TRANSCEIVER POWERED OFF
460
END

Fig.7

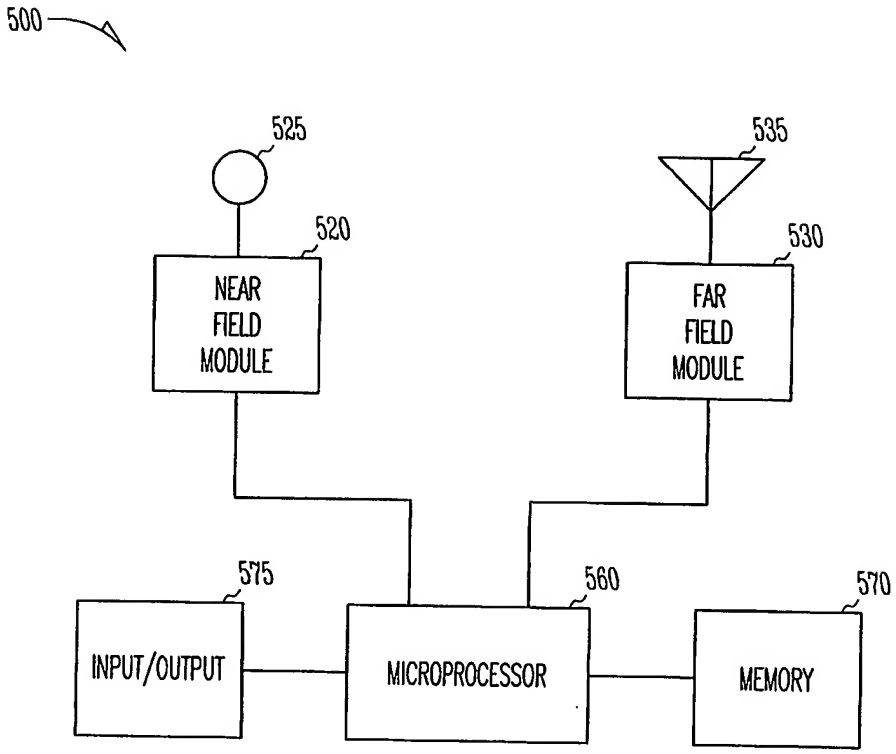
500
525
520
NEAR FIELD MODULE
535
530
FAR FIELD MODULE
575
INPUT/OUTPUT
560
MICROPROCESSOR
570
MEMORY

Fig.8

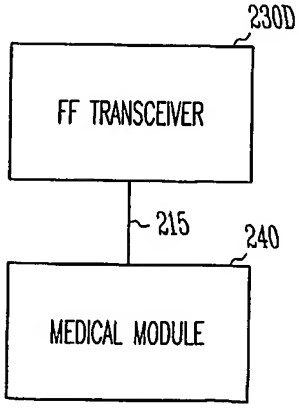
230D
FF TRANSCEIVER
215
240
MEDICAL MODULE

Fig.9

INTERNATIONAL SEARCH REPORT

ıtional Application No
PCT/US 02/40488

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61N1/372

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 807 397 A (BARRERAS FRANCISCO J) 15 September 1998 (1998-09-15) abstract column 8, line 37 -column 10, line 29; figure 1	1-8,11, 12,14-18 19
X Y	US 6 263 246 B1 (DUDDING CHARLES H ET AL) 17 July 2001 (2001-07-17) the whole document	20, 22-33, 39-49 19

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 April 2003	09/05/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gaillard, A

INTERNATIONAL SEARCH REPORT

ernational application No.
PCT/US 02/40488

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 34-38
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

tional Application No
PCT/US 02/40488

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		AU 4652996 A	24-07-1996
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		JP 3154062 B2	09-04-2001
		JP 10509901 T	29-09-1998
		WO 9620754 A1	11-07-1996
		US 5769877 A	23-06-1998
US 6263246 B1	17-07-2001	US 2001012955 A1	09-08-2001